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Reduction in incidence and prevalence of *Plasmodium falciparum* in under-5-year-old children by permethrin impregnation of mosquito nets*

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The malaria incidence and prevalence rates among children who slept under permethrin-impregnated mosquito nets in four villages near Madang, Papua New Guinea, were compared with the rates among children who slept under unimpregnated nets in four paired control villages. Immediately following a parasitological survey in the eight villages, malaria parasites were cleared from the children with chemotherapy, and the mosquito nets in the four experimental villages were impregnated with permethrin. Follow-up parasitological surveys were performed 4 and 10 weeks later. Sporozoite rates in female mosquitos of the Anopheles punctulatus *complex decreased significantly in two of the experimental villages after impregnation. Also, the incidence of* Plasmodium falciparum *between the 4-week and 10-week surveys was significantly lower among the 0–4-year olds in villages with impregnated nets than in those with unimpregnated nets, leading to reduced prevalence of* P. falciparum *in this age group. Use of permethrin-impregnated nets had no effect on the incidence or prevalence of* P. falciparum *among 5–9-year olds or on that of* P. vivax *among the 0–4- or 5–9-year olds.*

Mosquito nets are used extensively in Papua New Guinea in areas where villagers have some access to cash income. Epidemiological surveys carried out in villages in the Madang area in 1983 during the wet season indicated that 81.9% of people reported using mosquito nets the previous night (*1*). While there was variation in mosquito net use between various parts of the Madang area, this did not correlate with the consistent differences in childhood spleen and parasite rates observed in the different locations (*1*). However, a study in the Gambia has demonstrated a lower spleen rate among under-7-year olds who slept under mosquito nets compared with those without nets (*2*).

Impregnation of mosquito nets with synthetic pyrethroids to reduce the incidence and prevalence of malaria has recently received much attention (*3*).[a, b] Permethrin impregnation of mosquito nets could theoretically reduce malaria transmission in two ways: by decreasing a mosquito population as a whole by increasing mosquito mortality; and by providing protection to individuals sleeping under treated nets (or in houses with treated nets) by a repellency or irritancy effect, or through inhibition of biting.

A study in Gonoa vilage, near Madang, showed that use of permethrin-impregnated nets caused a significant reduction in the prevalence of *Plasmodium falciparum* among 1–4-year olds (but not among other age groups) compared with those in a control village supplied with untreated nets.[c] In view of this

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[a] DARRIET, F. ET AL. *Evaluation of the efficacy of permethrin-impregnated intact and perforated mosquito nets against vectors of malaria.* Unpublished document WHO/VBC/84.899, 1984.

[b] SCHRECK, C. E. & SELF, L. S. *Treating mosquito nets for better protection from bites and mosquito-borne disease.* Unpublished document WHO/VBC/85.914, 1985.

[c] MILLEN, D. B. *Alternative methods of personal protection against the vectors of malaria in lowland Papua New Guinea with emphasis on the evaluation of permethrin-impregnated bed nets.* MPM thesis, Simon Fraser University, 1986.

result, we have carried out a further trial in several villages that lie within the study area of the malaria research programme of the Papua New Guinea Institute of Medical Research, previously described by Cattani et al. (*1, 6*)

There is a large variation in the mosquito biting rates and the proportions of the different vectors (*Anopheles farauti*, *A. koliensis* and *A. punctulatus*) among villages near Madang. These three species differ in the extent to which they bite humans and in their feeding and resting behaviour (*4, 5*). Entomological inoculation rates have been reported by Burkot et al. (*7*). *A. longirostris* and *A. bancrofti*, which rarely bite humans in the area, have not been found infected with sporozoites. For this study, we selected four pairs of villages, where the entomological characteristics of the members of each pair were as similar as possible to each other.

MATERIALS AND METHODS

The study took place in the following pairs of villages:

—Panim and Butelgut: 9 km apart, 7 km and 10 km inland, altitude 200 m and 300 m, respectively; major vector, *A. punctulatus*.
—Budip and Mebat: 2 km apart, coastal; major vector, *A. koliensis*.
—Sah 1 and Sah 2: 200 m apart, 9 km inland, altitude 150 m; major vector, *A. punctulatus*.
—Dogia and Maraga: 3 km apart, coastal; major vectors, *A. farauti* and *A. koliensis*.

The first village in each pair was assigned to the "nets only" (N) group and the second to the "permethrin-impregnated nets" (PN) group. All villages, except Panim (where there is a government aid-post staffed by a health worker) had a "village aide" who had been trained to dispense chloroquine for presumptive treatment of fever (*8*).

Surveys of mosquito nets

In June and July 1985, use of mosquito nets in the study villages was surveyed (M1). Every household was visited, the names of those using each net were recorded, and each net then in use was marked with a number using indelible ink. At the same time, earlier demographic records were updated. During the succeeding three months, new cotton mosquito nets were sold in all eight villages at approximately half the cost price. Older or damaged nets tended to be replaced by new ones during this period.

In September 1985 a second survey of nets (M2) was conducted 1–2 weeks after the first parasitological survey (S1) and impregnation of the nets. The reference number of each net observed to be in use and the name(s) of the user(s) were recorded.

Parasitological surveys

Between September and December 1985 three parasitological surveys (S1, S2, and S3) of children under 10 years of age were carried out in the villages. Surveys took place at weeks 0, 4, and 10. Thick and thin blood films were made and spleen grades measured by the same examiner. Children (or their mothers) were asked whether they had used mosquito nets the previous night and those who attended the S1 survey were weighed and treated with chloroquine base (25 mg/kg body weight) administered over 3 days under supervision. In addition, a treatment dose of sulfadoxine/pyrimethamine[d] (calculated according to the child's weight) was given on the first day. The combination of drugs was used because resistance to both chloroquine and sulfadoxine/pyrimethamine has been reported in this area (*1, 9*). Babies under 1 month of age, however, were not given sulfadoxine/pyrimethamine. Chloroquine was available for sick children at surveys S2 and S3, and throughout the study from the resident village aides or aid-post orderly.

Within 3 days of the first parasitological survey (S1), mosquito nets in the four PN villages (Butelgut, Maraga, Mebat, and Sah 2) were impregnated, as described by Schreck & Self,[e] with permethrin[f] at a nominal concentration of 0.5 g/m^2. Nets were dipped (either individually or in batches of up to 10) in sufficient insecticide solution to completely soak them without causing subsequent dripping. The nets were then laid on a plastic sheet to dry; final drying of the nets was accomplished by hanging them up on a line. Nets were ready for use on the night after impregnation. The identification numbers of the impregnated nets were recorded.

Entomological surveys

A team of four mosquito collectors visited each village (except Sah 1, which is contiguous with Sah 2) on four consecutive nights, two or three times during each of the 3-month periods preceding and following the first parasitological survey. Indoor and outdoor landing catches were performed in two shifts between 18h 00 and 06h 00, and the collectors were rotated between the shifts and indoor and outdoor locations. Mosquitos were counted, identified, and stored frozen for determination of sporozoite rates of *P. falciparum* and *P. vivax* by enzyme-linked immunosorbent assay (ELISA) (*10, 11*).

[d] Fansidar®, F. Hoffmann-La Roche.
[e] See footnote *b*, p. 869.
[f] Wellcome.

RESULTS

Mosquito net use and impregnation of nets

In the first net survey (M1) before distribution of new nets, 92.5% of 120 children in the PN group and 89.3% of 121 children in the N group slept under mosquito nets. In the second net survey (M2), over 96% of people in all villages slept under mosquito nets (Table 1) and only one child (in the N group) did not possess a net (number of children surveyed in PN villages = 126; number in N villages = 117). When questioned at S1, S2, and S3, over 98.6% of children reported having used nets the previous night.

Acceptance of the permethrin impregnation in the PN villages was over 93% except in Maraga, where 60.6% of nets were impregnated (Table 1). Nevertheless, 76% of houses in Maraga (number surveyed = 29) had at least one impregnated net in use. Overall, 82.1% of children under 10 years in the PN villages used nets that were impregnated with permethrin.

Survey attendance and drug treatment

Survey S1 was attended by 142 (94.7%) of the children aged under 10 years in the PN villages and by 136 (82.9%) in the N villages. Attendance was over 80% in all villages except Dogia, where it was 70.7%. There was no significant difference between the two sets of villages in the proportion of children receiving full treatment with chloroquine (76.9% in PN and 70.6% in N villages) or sulfadoxine/pyrimethamine (89.5% and 93.4% in the PN and N villages, respectively). The 15 children who did not receive a treatment dose of one or other drug (i.e., no sulfadoxine/pyrimethamine and less than 3 days of chloroquine) were excluded from the analysis, leaving 133 in the PN group and 130 in the N group, of whom 73 (54.9%) and 69 (53.1%), respectively, were aged 0–4 years. Survey S2, which took place 4 weeks after S1, was attended by 110 (82.7%) children in the PN villages and 114 (87.7%) in the N villages, while 97 (72.9%) and 87 (66.9%) children, respectively, attended S3, held 10 weeks after S1.

Effect on parasite rates

The overall parasite prevalence rate fell from 47.4% at S1, following drug treatment, to 5.4% at S2 for the PN group and from 32.3% to 6.1% for the N group. Of the 13 positive cases at S2, five were *P. falciparum*, six *P. vivax*, one mixed *P. falciparum* and *P. vivax*, and one *P. malariae*. Ten of these cases had received sulfadoxine/pyrimethamine and chloroquine, while the others had received chloroquine for 3 days.

The changes in prevalence of *P. falciparum* and *P. vivax* among those children examined in both S1 and S3 are shown in Table 2. The changes in incidence rates from S2 to S3 are shown in Table 3. These rates ignore conversions from negative to positive which reverted to negative again within this 6-week period. It was not possible to combine the results from the four N and the four PN villages to determine the statistical significance of the treatment difference shown in Tables 2 and 3 because of marked inter-village variation. Statistical tests were therefore applied to the difference between the PN and N groups for the change in prevalence in each village between S1 and S3 and to the incidence rates in each village from S2 to S3. Because of the small number of villages (in contrast to the number of participants), three separate tests were used: the paired Student's *t* test, the unpaired Student's *t* test, and the (unpaired) Mann-Whitney test. The first *t* test took the pairing of villages into account, while the Mann-Whitney test allowed for any deviation of the data from a normal distribution. Because of uncertainty as to the complete suitability of any particular test, the results from all

Table 1. Proportions of mosquito nets and of mosquito nets that were impregnated with permethrin

	Villages with nets only			Villages with impregnated nets			
Pair number	Village	% With nets	n^a	Village	% With nets	% Using impregnated nets	n^a
1	Panim	99.3	138	Butelgut	99.0	93.8	98
2	Budip	96.2	79	Mebat	97.9	97.0	102
3	Sah 1	96.0	75	Sah 2	98.6	95.8	73
4	Dogia	100.0	106	Maraga	99.3	60.6	138
Total		98.2	398		98.8	83.9	411

[a] Number of persons surveyed (adults and children).

Table 2. Percentage prevalence of *Plasmodium falciparum* and *P. vivax* at survey 1 (S1) and survey 3 (S3) among children aged 0–4 years and 5–9 years who attended both surveys[a]

		0–4-year olds						5–9-year olds					
		Nets only			Nets + permethrin			Nets only			Nets + permethrin		
	Village pair	S1	S3	*n*	S1	S3	*n*	S1	S3	*n*	S1	S3	*n*
P. falciparum	1	7.1	35.7	14	27.3	18.2	11	15.4	7.7	12	44.4	44.4	6
	2	7.7	23.1	13	16.7	0	12	33.3	25.0	12	46.2	23.1	13
	3	0	33.3	9	36.4	0	11	33.3	0	9	87.5	0	8
	4	38.5	30.8	13	18.2	9.1	22	100.0	25.0	4	54.5	18.2	11
Total[a]		14.3	30.6	49	23.2	7.1	56	34.2	13.2	38	56.1	22.0	41
P. vivax	1	0	0	14	9.1	9.1	11	7.7	7.7	13	44.4	33.3	9
	2	30.8	15.4	13	16.7	33.3	12	41.7	16.7	12	23.1	7.7	13
	3	0	22.2	9	27.3	45.5	11	22.2	22.2	9	25.0	87.5	8
	4	23.1	38.5	13	4.5	18.2	22	25.0	25.0	4	9.1	63.6	11
Total[a]		14.3	18.4	49	12.5	25.0	56	23.7	15.8	38	24.4	43.9	41

[a] Expressed as a percentage of the total number of children examined in the four villages for each species and age group.

three tests were considered together and interpreted with caution.

The *P*-values obtained for the three tests are given in Table 4. The tests were performed on two sets of data: firstly, on the results obtained when all children in the PN villages were included, and secondly when only those children known to be sleeping under impregnated nets were included, 81 and 74 of whom attended S2 and S3, respectively. Significant differences in the prevalence or incidence between the PN and N villages were observed among 0–4-year olds for *P. falciparum*. While in no instance did all three

Table 3. Incidence rates of *Plasmodium falciparum* and *P. vivax* among children aged 0–4 years and 5–9 years (conversions from negative at S2 to positive at S3)

		0–4-year olds				5–9-year olds			
		Nets only		Nets + permethrin		Nets only		Nets + permethrin	
	Village pair	Incidence (%)	*n*	Incidence (%)	*n*	Incidence (%)	*n*	Incidence (%)	*n*
P. falciparum	1	35.7	14	20.0	10	10.0	10	50.0	8
	2	20.0	10	0	12	25.0	12	23.1	13
	3	33.3	9	0	11	0	9	0	8
	4	25.0	12	15.4	13	25.0	4	28.6	7
Total		28.9	45	8.7	46	14.3	35	25.0	36
P. vivax	1	0	14	11.1	9	9.1	11	33.3	9
	2	22.2	9	36.4	11	16.7	12	8.3	12
	3	22.2	9	40.0	10	22.2	9	87.5	8
	4	41.7	12	23.1	13	25.0	4	71.4	7
Total		20.5	44	27.9	43	16.7	36	44.4	36

Table 4. Significance level of tests applied to differences between villages with nets (N) and those with nets + permethrin (PN) for the prevalence and incidence of *Plasmodium falciparum* in children aged 0–4 years

	P-value			No. in sample	
	Paired *t* test	Unpaired *t* test	Mann-Whitney test	N villages	PN villages
All 0–4-year-olds in PN villages					
Prevalence change (S1 to S3)	0.086	0.020	0.029	49	56
Incidence (S2 to S3)	0.030	0.021	0.029–0.057[a]	45	46
Only impregnated net users in PN villages					
Prevalence change (S1 to S3)	0.024	0.024	0.057	49	41
Incidence (S2 to S3)	0.051	0.059	0.057	45	36

[a] An exact *P*-value cannot be obtained because the incidence rates in one N village and one PN village were equal.

tests give *P*-values <0.05, in all instances they were <0.1. Restriction of the analysis of the change in prevalence only to known impregnated net users increased the level of significance observed for the paired *t* test, but not for the other two tests. Using the restricted data set for the test of incidence rate apparently decreased the significance level, possibly owing to the decreased sample size. Tests on the prevalence and incidence of *P. vivax* in the 0–4-year olds and of both *P. falciparum* and *P. vivax* in the 5–9-year olds gave *P*-values that were always >0.1.

Thirteen children had *P. falciparum* gametocytes at S1 (six in the PN and seven in the N group), while at S3 there were zero and three cases, respectively, in the two groups. The reduction in prevalence of *P. falciparum* gametocytes in the PN group was significant ($P=0.041$, Fisher's exact test). At S1 the prevalence of *P. malariae* was 3.0% and 3.1%, respectively, in the PN and N groups, while at S3 only one case of *P. malariae* (in the N group) was seen.

There were no significant differences between the PN and N villages with respect to either the change in prevalence of enlarged spleens between S1 and S3 or the incidence of this condition between S2 and S3.

Effect on mosquito biting and infection rates

Sporozoite rates of *P. falciparum* and *P. vivax* during each of the 3-month periods before and after survey S1 are shown in Table 5. Rates for the three vectors combined are also given (see Table 6). Sporozoite rates for each village in the periods "before" and "after" were compared using Fisher's exact test. There was no significant change in the sporozoite rate in any of the N villages. Among the PN villages, however, there was a significant decrease in the overall sporozoite rate in Mebat from 1.58% to 0.30% after net impregnation ($P=0.004$), and a significant decrease in Maraga from 0.23% to 0.04% ($P=0.033$) (Table 6). When statistical tests were performed on the two malaria species separately, significant reductions in sporozoite rates of *P. vivax* in Mebat and *P. falciparum* in Maraga were observed ($P=0.028$ and 0.041, respectively). In Sah 2 and Butelgut, sporozoite rates were not significantly reduced by permethrin impregnation of the nets.

There was no significant difference between the proportions of each of the three vector species infected with *P. falciparum* or *P. vivax*, either before or after net impregnation (Table 5). Infection rates were highest for *A. punctulatus* and lowest for *A. farauti*, and this is largely a reflection of the different human blood indices of the three vectors.

Statistical tests were not performed on the mosquito biting rates (Table 6) because most of the variation is related to insect population fluctuations caused by climatic factors. Biting rates increased in all villages after S1, except in Butelgut. Multiplying the biting rates by the sporozoite rates gives the entomological inoculation rates shown in Table 7. The observed reductions in sporozoite rates indicate that, with the exception of *P. falciparum* in Butelgut, entomological inoculation rates for both *P. falciparum* and *P. vivax* decreased in all the PN villages after net impregnation, despite increases in the mosquito populations, while entomological inoculation rates increased in all the N villages, with the exception of *P. falciparum* in Dogia.

DISCUSSION

In this study, we attempted to reduce transmission of *P. falciparum* and *P. vivax* by impregnating mosquito nets with permethrin on a village basis. By

Table 5. Number of *Anopheles farauti, A. koliensis,* and *A. punctulatus* that were positive for *Plasmodium falciparum* and *P. vivax* sporozoites in the 3 months before and after S1

	Before S1									After S1								
	A. farauti			*A. koliensis*			*A. punctulatus*			*A. farauti*			*A. koliensis*			*A. punctulatus*		
	Pf[a]	Pv[b]	Total[c]	Pf	Pv	Total	Pf	Pv	Total	Pf	Pv	Total	Pf	Pv	Total	Pf	Pv	Total
N villages																		
Panim	0	0	0	0	1	123	6	1	416	0	0	2	2	1	62	12	8	694
Budip	0	0	23	0	0	42	0	0	0	1	0	26	7	2	309	0	0	2
Dogia	3	2	3307	2	1	601	0	0	52	3	5	4071	0	0	848	1	0	95
Total	3	4	3330	2	2	766	6	1	468	4	5	4099	9	3	1219	13	8	791
Sporozoite rate (%)			0.2			0.5			1.5			0.2			1.0			2.7
PN villages																		
Butelgut	0	0	0	0	0	47	1	9	300	0	0	1	0	0	7	2	2	129
Mebat	0	0	45	3	2	342	1	3	181	0	0	34	2	1	934	0	1	349
Sah 2	0	0	0	0	0	25	7	0	290	0	0	25	1	0	32	2	0	293
Maraga	6	4	6224	3	2	783	1	0	40	0	1	2387	0	0	256	0	0	3
Total	6	4	6269	6	4	1197	10	12	811	0	1	2447	3	1	1229	4	3	774
Sporozoite rate (%)			0.2			0.8			2.7			0.04			0.3			0.9

[a] Pf = *Plasmodium falciparum.*

[b] Pv = *Plasmodium vivax.*

[c] Total = total number analysed.

Table 6. Mosquito biting rates (all species combined) and sporozoite rates in the 3 months before and after S1

Village	Pair No.	No. of bites per person per night		Sporozoite rate (%)							
				Before S1				After S1			
		Before S1	After S1	Pf[a]	Pv[b]	Total	*n*	Pf	Pv	Total	*n*
N villages											
Panim	1	23.7	31.9	1.11	0.37	1.48	539	1.85	1.19	3.03	758
Budip	2	2.7	21.0	0	0	0	65	2.37	0.59	2.97	337
Dogia	4	440.1	596.4	0.13	0.13	0.25	3960	0.08	0.10	0.18	5014
PN villages											
Butelgut	1	19.5	5,7	0.29	2.59	2.88	347	1.46	1.46	2.92	137
Mebat	2	32.1	83.8	0.70	0.88	1.58	568	0.15	0.15	0.30	1327
Sah 2	3	13.4	14.6	2.22	0	2.22	315	0.86	0	0.86	350
Maraga	4	485.2	855.2	0.14	0.09	0.23	7047	0	0.04	0.04	2646

[a] Pf = *Plasmodium falciparum*.
[b] Pv = *Plasmodium vivax*.

eradicating the majority of infections with chemotherapy, it was possible to compare the incidence rates as well as the prevalence rates following impregnation. The incidence of *P. falciparum* among 0–4-year olds was lower in the villages with permethrin-impregnated nets than in those with unimpregnated nets, resulting in a lower prevalence among children of this age group 10 weeks after net impregnation. The *P*-values for differences in *P. falciparum* incidence and prevalence rates among 0–4-year olds determined using three different statistical tests were all <0.1, and several were <0.05. This was not the case among 5–9-year olds or for the incidence and prevalence of *P. vivax* in either age group, where all *P*-values obtained were >0.1.

Table 7. Entomological inoculation rates 3 months before and after S1

	Pair No.	Entomological inoculation rate			
		Plasmodium falciparum		*Plasmodium vivax*	
		Before S1	After S1	Before S1	After S1
N villages					
Panim	1	0.261	0.590	0.133	0.380
Budip	2	0	0.498	0	0.124
Dogia	4	0.572	0.477	0.572	0.596
PN villages					
Butelgut	1	0.057	0.083	0.505	0.083
Mebat	2	0.225	0.126	0.282	0.126
Sah 2	3	0.297	0.126	0	0
Maraga	4	0.679	0	0.437	0.342

Millen compared the prevalence of malaria among all age groups in two villages in the Madang area, in one of which nets impregnated with 0.2 g/m^2 permethrin were used, while in the other, the control village, unimpregnated nets were used.[g] Surveys conducted 3 and 7 months after initial net impregnation indicated that the prevalence of *P. falciparum* among 1–4-year olds was lower in the village that used impregnated nets than in the control village. Although the 3-month survey found that the rates were not significantly different, in the 7-month survey the 50% prevalence among 1–4-year olds in the experimental village was significantly lower than the 77.7% in the control village ($P<0.05$). Rates for *P. falciparum* gametocytes in all age groups were also significantly lower (3.6%) in the experimental than in the control village (7.3%) at the 7-month survey. Unlike our study, no effect was observed on entomological parameters; however, the permethrin concentration used in Millen's study was less than half of that we used.

In neither Millen's nor our study was an effect observed on the prevalence of *P. vivax*. This is not surprising, since strains of *P. vivax* from Papua New Guinea relapse rapidly, usually within 50 days of the end of the primary attack (*12*). Thus, since an antihypnozoite drug was not used, most of the observed *P. vivax* infections were probably relapses.

Previous studies of permethrin-impregnated mosquito nets have reported conflicting evidence about

[g] See footnote *c*, p 869.

the effect of the insecticide on mosquitos. For example, Darriet et al. found that the repellent and irritant effects of permethrin reduced by 70% the entry rate of *A. gambiae* and *A. funestus* into huts and decreased the engorgement rate by 10–20% in those that entered.[h] In addition, permethrin caused a mortality rate of 17% among mosquitos that did enter the huts. However, Lines et al. (*3*) found no consistent difference between the numbers of *A. arabiensis* mosquitos that entered huts with impregnated or unimpregnated nets; the major effect of net impregnation was to inhibit feeding, although a mortality rate of 50% among those mosquitos that did enter and feed was observed. In a recent study in Madang, permethrin-impregnated nets did not affect mortality rates for *A. farauti*; although the overall population decreased, the oviposition cycle became irregular, and the human blood index was reduced (*14*). This suggests that the reductions in sporozoite rates observed in our study were probably caused by repellent effects that prevented mosquitos from transmitting and picking up infections, rather than by increased mosquito mortality. Significant decreases in sporozoite rates were observed only in villages where *A. koliensis* and *A. farauti* were the major vectors. These may be more easily diverted to non-human hosts by permethrin than *A. punctulatus*, which has a greater preference for human blood (*4*), and consequently a higher sporozoite rate.

It is not clear why the 0–4-year olds appeared to benefit more than the 5–9-year olds from permethrin impregnation of their mosquito nets, although the former may spend a longer time sleeping indoors and receive more frequent antimalarial therapy than older children. In view of this, permethrin-impregnated nets may provide enough extra protection to reduce infection rates. Maximum prevalence rates of *P. falciparum* in the Madang area have been reported among 5–9-year olds (*1*), and this was confirmed by the present study at survey S1. However, incidence rates in the "nets only" group were lower among 5–9-year olds than 0–4-year olds, and further studies are required to clarify this. A study using matched pairs of children would circumvent the problem of inter-village variation in parasite rates and would enable the effectiveness of impregnated nets, used on an individual rather than a village basis, to be investigated.

Limited studies have indicated that permethrin has a low toxicity to mammals (*13*) but it is toxic to fish. Therefore, adequate precautions in handling the permethrin concentrate should be taken when treating nets to prevent accidental poisoning or contamination of water sources.

The effects of permethrin impregnation observed in both this study and that of Millen[h] are encouraging, since the 0–4-year olds are at the greatest risk of developing severe complications of *P. falciparum* malaria. In areas where many people already possess mosquito nets, as do the majority around Madang, the method is extremely cheap (approximately US$ 0.50 per net) and popular, although apparently more because permethrin kills head-lice and bed bugs than because of its perceived effectiveness against malaria. Also, rather than requiring a concerted simultaneous campaign over a large area, this method of reducing the incidence of malaria, which does not require sophisticated equipment, could be introduced through small-scale community efforts.

[h] See footnote *a*, p. 869.

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RÉSUMÉ

BAISSE DE L'INCIDENCE ET DE LA PRÉVALENCE DE *PLASMODIUM FALCIPARUM* CHEZ LES ENFANTS DE MOINS DE 5 ANS GRÂCE À L'UTILISATION DE MOUSTIQUAIRES IMPRÉGNÉES DE PERMÉTHRINE

L'incidence et la prévalence du paludisme chez des enfants dormant sous des moustiquaires imprégnées de perméthrine dans quatre villages situés à proximité de Madang, en Papouasie-Nouvelle-Guinée, ont été comparées à celles

mesurées chez des enfants de quatre villages témoins appariés, qui dormaient sous des moustiquaires non imprégnées. Dans les deux groupes de villages, les espèces vectrices et leur densité étaient analogues. Immédiatement après une enquête parasitologique réalisée dans les huit villages et après l'élimination de la parasitémie chez les enfants par chimiothérapie, les moustiquaires sous lesquelles dormaient les enfants ont été imprégnées de perméthrine dans les quatre villages expérimentaux. Les enquêtes à domicile ont montré que 98,8% des habitants des villages expérimentaux dormaient sous des moustiquaires, de même que 98,2% des habitants des villages témoins, et que 83,9% des moustiquaires utilisées dans les villages expérimentaux avaient été imprégnées de perméthrine. Des enquêtes parasitologiques de suivi ont été réalisées quatre et dix semaines plus tard chez les enfants de moins de 10 ans. Dans deux des villages expérimentaux (où les principaux vecteurs étaient *Anopheles koliensis* et *A. farauti*), on a observé une réduction importante, de cinq fois, des taux de sporozoïtes après imprégnation des moustiquaires. Dans les deux autres villages expérimentaux (où le principal vecteur était *A. punctulatus*) et dans les quatre villages témoins, on n'a observé aucune modification significative des taux de sporozoïtes. L'incidence de *Plasmodium falciparum* entre les deux enquêtes de suivi était sensiblement plus faible chez les enfants de 0 à 4 ans des villages utilisant des moustiquaires imprégnées que chez les enfants du même âge des villages témoins, ce qui s'est traduit par une baisse de la prévalence de *P. falciparum* dans ce groupe d'âge. L'emploi de moustiquaires imprégnées de perméthrine n'a pas eu d'effet sur l'incidence ni sur la prévalence de *P. falciparum* chez les enfants de 5 à 9 ans ni sur celles de *P. vivax* chez les enfants de 0 à 9 ans. Les résultats de cette étude, de même que ceux d'études antérieures, semblent indiquer que l'imprégnation des moustiquaires par la perméthrine peut être dans cette région un moyen simple et efficace de réduire l'incidence et la prévalence de *P. falciparum* chez les enfants de moins de 5 ans.

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